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ORIGINAL PAPER

Does tree species composition control the soil carbon stocks of the Hyrcanian forest in the Northern Iran? (A case study in Guilan province, Iran)

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Abstract: This work studied the effects of tree species composition on soil carbon storage in five mixed stands dominated by oriental beech and grown in the western Caspian region in Guilan province, called Astara, Asalem, Fuman, Chere and Shenrud. The thickness of the litter layer, soil characteristics, tree composition and percentage of canopy coverage were measured in each stand. Total soil organic carbon differed significantly by stand. Total (organic) carbon stores at Fuman, which had the lowest tree species richness with 2 species and least canopy coverage (75%), were significantly (p <0.05) higher than at other locations. Carbon storage in topsoil (0–10 cm) was significantly lower in Shenrud, which had the highest tree species richness with 5 species and highest canopy coverage (95%). The high percentage of canopy coverage in Shenrud probably limited the conversion of litter to humus. However, in the second soil layer (10–25 cm), Asalem, with high tree species richness and canopy coverage, had the highest carbon storage. This can be explained by the different rooting patterns of different tree species. In the Hyrcanian forest. According to the results, it can be concluded that not only tree composition but also canopy coverage percentage should be taken under consideration to manage soil carbon retention and release.

Keywords: beech forest, canopy coverage, soil carbon stocks, tree composition

Introduction

In terrestrial ecosystems, soil is the largest reservoir of carbon (C) and plays an essential role in determining the concentration of atmospheric CO_2 (Johnson and Curtis 2001). Forests form an active carbon pool accounting for 60 percent of carbon storage on the earth's land surface and, in particular, forest soils have an important function in this regard (Gower 2003).

Changes in soil properties due to different forest management and silvicultural methods affect soil C pools and the carbon budget of the atmosphere (Brown and Lugo 1990; Adger et al. 1992; Johnson 1992; McPherson et al. 1993).

Tree species composition, which can be altered by silvicultural methods, affects soil carbon storage by direct and indirect effects on the quality and quantity of litter fall, throughfall and stemflow, soil properties, rooting patterns, soil respiration and consequently the nutrient availability in forest stands Berger et al. 2002).

During the recent four decades, oriental beech (*Fagus orientalis*) stands in Caspian forests have been chiefly managed using shelterwood and selection methods (Sagheb-Talebi and Schütz 2002). These created gaps in pure stands of beech and the gaps were occupied by light-demanding tree species. The sivilcultural objective was to exploit the hypothesized positive impact of mixed beech stands on the biogeochemistry of forest ecosystems.

Several studies have examined carbon storage in the soil of pure and mixed beech stands (Son et al. 2004; Kim et al. 2009). Little is known, however, about the impact of tree species composition on carbon storage in the soil of mixed beech-dominated forests. The objective of this study was to quantify the relationships between tree species composition of beech-dominated forests and soil carbon stocks in the western Caspian region of northern Iran.

Materials and methods

Study sites description

The research was conducted in five stands dominated by *Fagus orientalis* grown in the western Caspian region in Guilan province and named Astara, Asalem, Fuman, Chere, and Shenrud. The thickness of the litter layer, soil characteristics, and tree composition were measured in three 50 m diameter circular plots in each stand using methods described below.

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Measurement of the litter layer thickness

The thickness of the litter layer was measured using a rigid aluminum bar held parallel to the soil surface and perpendicular to a ruler held vertical to and in contact with the soil surface. The thickness of the litter layer was measured (Fig. 1) at four points along the bar by measuring the distance from the base of the bar to the soil surface with a ruler (Marimon-Junior and Hay 2008).

Fig. 1. Measurement of the litter layer thickness

Soil sampling and analysis

Soil samples were gathered at three points along the circular plot diameters (center, east and west) (Fig. 2) from three layers, 0–10 cm, 10–25 cm, and 25–40 cm. The soil core was carefully collected in each soil layer for estimating the soil bulk density. Samples of about 2 kg of soil from each soil layer were collected, air-dried, passed through a 2-mm sieve, and stored in the laboratory for analysis.

Soil analyses were carried out by the following methods: particle size distribution by the hydrometer method (Gee & Bauder 1986); total soil organic carbon was determined by the Walkley-Black wet oxidation method (Nelson and Sommer 1982); pH was measured using a mixture of soil and deionized water (1:1, w/v) with a glass electrode (McLean 1982); and electrical conductivity (EC) was measured by a conductivity meter in saturation extracts. The core method was used to determine bulk density (Blake and Hartge 1986). Total soil C storage (Ct, kg·ha^{-1}) was calculated by equation (1) (Guo and Gifford 2002):

$$\mathrm{C_t} = B_D \times C_\mathrm{c}\% \times D \tag{1}$$

where, B_D is the soil bulk density (g·cm^{-3}), C_c % is the soil carbon content, and D is the soil sampling depth (cm).

Tree composition

Tree composition of the stands also was determined in the circular plots. All living trees ≥30 cm diameter at breast height were identified and species ratios were calculated as percentages.

Canopy coverage percentage

Five digital photographs were taken using a standard digital camera in each plot, one photograph at the centre and the others at cardinal points. The canopy coverage percentage on the photographs was determined by image analysis software, ImageJ (National Institutes of Health, Maryland, USA) (Korhonen et al. 2006).

Results and discussion

Asalem and Shenrud were the richest stands with five species each and Fuman had the lowest richness with two species (Table 1). The locations with the highest species richness also had the highest percentage of canopy coverage (95%) and litter thickness (11 cm).

Table 1. Tree composition, percent canopy coverage and thickness of the litter layer in studied

Site name	Composition	Percentage of canopy coverage	Thickness of the litter layer (cm)
Astara	50% *Fagus orientalis*, 40% *Carpinus betulus* & 10% *Acer velutinum*	85	7.5
Asalem	80% *Fagus orientalis*, 5% *Carpinus betulus*, 3% *Tilia begonifolia*, 7% *Acer velutinum* & 5% *Acer cappadocicum*	95	11
Fuman	85% *Fagus orientalis*, 15% *Carpinus betulus*	75	5
Chere	70% *Fagus orientalis*, 20% *Carpinus betulus* & 10% *Acer velutinum*	85	7.5
Shenrud	80% *Fagus orientalis*, 10 % *Carpinus betulus*, 3% *Tilia begonifolia*, 4% *Acer velutinum* & 3% *Acer cappadocicum*	95	11

The soil pH ranged from 5.1 in Fuman to 7.8 in Shenrud. Asalem and Fuman were classified as strongly acidic (pH 5.1–5.5), Astara and Chere as moderately acidic (pH 5.5–6.0) and Shenrud as slightly alkaline (pH 7.4–7.8), (Table 2).

Soil textures were sandy loam in Astara, loam in Asalem, Fuman and Chere, and clay in Shenrud. Cumulative carbon stores of mineral soil and total C stores to 40 cm depth are shown in Fig. 2. Total organic carbon stores at Fuman (152 kg·ha^{-1}) were significantly higher (p □0.05) than at Shenrud (94 kg·ha^{-1}). Variation in total organic carbon by stand was attributed to the following factors: (a) accumulation of the mineralizable component of carbon (Berger et al. 2002) in the acidic soils of Fuman; (b) conversion of the litter layer to humus and ultimately to or-

ganic carbon in Fuman due to the relatively low canopy coverage (70%) in comparison to other stands (Table 1).

Table 2. Selected soil characteristics in different locations

Location	Soil horizon (cm)	Organic carbon (%)	pH	Soil texture	EC	Bulk density ($g·cm^{-3}$)
Astara	0–10	5.61±(0.05)	5.49 ± (0.57)	Sandy loam	0.70±(0.17)	1.24±(0.15)
	10–25	1.39±(0.54)	5.90 ± (0.14)	Sandy loam	0.37±(0.07)	1.04±(0.12)
	25–40	1.59±(0.56)	5.46 ± (0.02)	Sandy loam	0.4±(0.12)	1.39±(0.19)
	MEAN	2.86±(2.38)	5.62 ± (0.24)		0.49±(0.18)	1.22±(0.17)
Asalem	0–10	4.23±(0.21)	6.00±(0.06)	Sandy loam	0.44±(0.13)	1.06±(0.04)
	10–25	4.15±(0.27)	5.18±(0.34)	Loam	0.44±(0.06)	1.21±(0.05)
	25–40	0.98±(0.28)	5.22±(0.05)	Loam	0.40±(0.05)	1.34±(0.07)
	MEAN	3.12±(1.84)	5.47±(0.46)		0.43±(0.02)	1.20±(0.14)
Fuman	0–10	4.27±(0.13)	5.16±(0.26)	Loam	1.08±(0.62)	1.57±(0.31)
	10–25	2.28±(0.52)	5.00±(0.21)	Loam	1.30±(0.39)	1.39±(0.18)
	25–40	2.06±(0.02)	5.35±(0.14)	Loam	1.71±(0.09)	1.15±(0.20)
	MEAN	2.87±(1.21)	5.17±(0.17)		1.36±(1.36)	1.37±(0.20)
Chere	0–10	3.59±(0.32)	5.48±(0.52)	Loam	0.95±(0.14)	1.22±(0.51)
	10–25	2.33±(0.29)	5.96±(0.11)	Loam	0.68±(0.24)	1.17±(0.22)
	25–40	2.02±(0.04)	5.74±(0.34)	Loam	0.84±(0.24)	1.29±(0.02)
	MEAN	2.64±(0.83)	5.72±(0.24)		0.83±(0.13)	1.23±(0.06)
Shenrud	0–10	1.84±(0.34)	7.73±(0.10)	clay	0.71±(0.02)	1.39±(0.13)
	10–25	1.48±(0.46)	7.68±(0.21)	clay	0.64±(0.09)	1.6±(0.33)
	25–40	1.74±(0.38)	7.63±(0.16)	clay	0.65±(0.17)	1.15±(0.24)
	MEAN	1.69±(0.18)	7.72±(0.06)		0.67±(0.03)	1.38±(0.22)

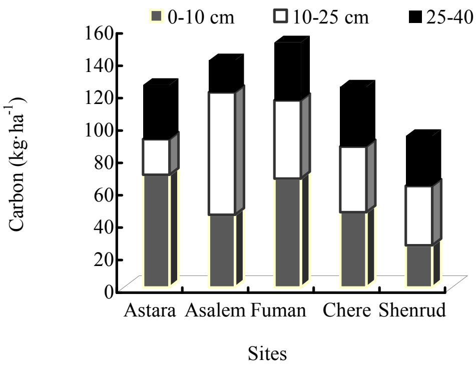

Fig. 2. Total soil carbon storage to 40 cm depth

Carbon stores in topsoil (0–10cm) was significantly lower at Shenrud (26.10 $kg·ha^{-1}$) than at other stands ($p < 0.05$). This was probably due to higher canopy coverage (95%) at Shenrud that slowed conversion of litter to humus. However, in the second soil layer (10–25 cm), Asalem had the highest carbon storage (Fig. 3) and also had high species richness and high canopy coverage. This might be explained by the different rooting patterns of tree species at Asalem.

The rooting pattern not only directly affects carbon flux to the soil profile but also, through root movement due to wind action on the canopy, affects soil porosity, aeration and ultimately the decomposition rate of organic matter (Berger and Hager 2000). In the deepest soil layer (25–40 cm), carbon storage did not vary significantly by tree stand.

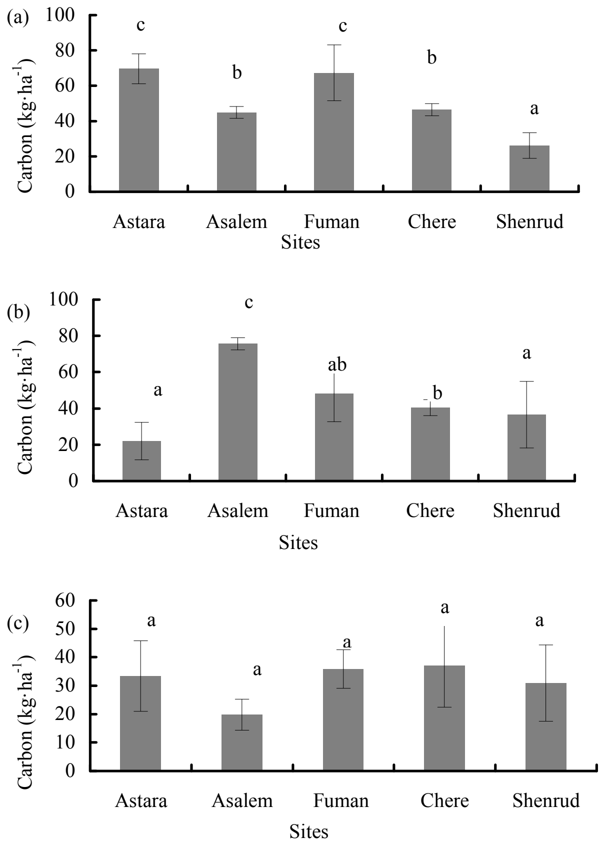

Fig. 3. Organic carbon stores by soil layer: 0–10cm (a), 10–25 cm (b), 25–40cm (c). Bars show S.D. Means with the same letter are not significantly different at p<0.05 by Tukey's HSD procedure.

In conclusion, in the Hyrcanian forest, not only tree composition but also canopy coverage percentage should be taken into consideration to manage soil carbon retention and release.

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